ZooKeys 466: 77–94 (2014)
doi: 10.3897/zookeys.466.8047
http://zookeys.pensoft.net

RESEARCH ARTICLE

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Four new species of hangingflies (Insecta, Mecoptera, Bittacidae) from the Middle Jurassic of northeastern China

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Academic editor: *Michael Engel* | Received 5 June 2014 | Accepted 26 November 2014 | Published 19 December 2014

http://zoobank.org/19C20324-B7A5-48EB-BBA4-5D849697EA23

Citation: Liu S-L, Shih C-K, Ren D (2014) Four new species of hangingflies (Insecta, Mecoptera, Bittacidae) from the Middle Jurassic of northeastern China. ZooKeys 466: 77–94. doi: 10.3897/zookeys.466.8047

Abstract

Two new species of *Mongolbittacus* Petrulevičius, Huang & Ren, 2007, *M. speciosus* **sp. n.** and *M. oligophlebius* **sp. n.**, and two new species of *Exilibittacus* Yang, Ren & Shih, 2012, *E. foliaceus* **sp. n.** and *E. plagioneurus* **sp. n.**, in the family Bittacidae, are described and illustrated based on five well-preserved fossil specimens. These specimens were collected from the late Middle Jurassic Jiulongshan Formation of Daohugou, Inner Mongolia, China. These new findings enhance our understanding of the morphological characters of early hangingflies and highlight the diversity of bittacids in the Mid Mesozoic ecosystems.

Keywords

Mongolbittacus, *Exilibittacus*, Jiulongshan Formation, Daohugou, Insect fossil

Introduction

Bittacidae, a large family of Mecoptera commonly called hangingflies, live mainly in the temperate or warm tropical climates. The fifth tarsomere of bittacids can be folded against the fourth with the only one claw at pretarsus (Petrulevičius et al. 2007). Since this special tarsi structure is shared by a sister group of Cimbrophlebiidae (Archibald 2009; Yang et al. 2012a), it is suggested that this morphological character may be

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an apomorphy. So far, there are 16 extant genera with about 270 described extant species (Krzemiński 2007; Yang et al. 2012b). For fossil records, there are 28 genera comprising 52 species as summarized by Li and Ren (2009b). Since then, two genera, *Decoribittacus* Li & Ren, 2009 and *Exilibittacus* Yang, Ren & Shih, 2012, with three species have been described (Li et al. 2009a, Yang et al. 2012b). In addition, up to date, about 20 genera have been described from the Jurassic (Handlirsch 1906, 1939; Ansorge 1993; Tillyard 1933; Ren 1993, 1997; Novokshonov 1993a, 1993b, 1997; Petrulevičius et al. 2007; Li et al. 2008, 2009a; Yang et al. 2012a, 2012b). The age distribution for these fossil genera suggests that the broadest diversity of Bittacidae occurred during the Jurassic, and the earliest fossil record of Bittacidae is *Archebittacus exilis* Riek, 1955 from the Upper Triassic of Mt. Crosby, Australia (Riek 1955).

Until now, 11 fossil genera of Bittacidae from the late Middle Jurassic to the Early Cretaceous have been recorded in China: *Liaobittacus* Ren, 1993 from the Haifanggou Formation; *Megabittacus* Ren, 1997 and *Sibirobittacus* Sukatcheva, 1990 from the Yixian Formation; *Neorthophlebia* Handlirsch, 1906 from the Tuodian Formation; *Preanabittacus* Novokshonov, 1993, *Mongolbittacus* Petrulevičius, Huang & Ren, 2007, *Formosibittacus* Li, Ren & Shih, 2008, *Jurahylobittacus* Li, Ren & Shih, 2008, *Decoribittacus* Li & Ren, 2009, *Karattacus* Novokshonov, 1997, and *Exilibittacus* Yang, Ren & Shih, 2012, all from the Jiulongshan Formation. A list of 14 species in 11 genera is summarized in Table 1.

Herein we describe four new species of Bittacidae, based on five recently collected fossil specimens from the Jiulongshan Formation of Daohugou, Ningcheng County, Inner Mongolia, China. The section at Daohugou Village is composed of grey tuffaceous sandstone and sandy mudstone (Ren et al. 2002). This formation has yielded abundant and diverse insect fossils (Ren et al. 2010), such as Lepidoptera (Zhang et al. 2013), Mecoptera (Ren et al. 2009; Wang et al. 2012; Wang et al. 2014), Hymenoptera (Shih et al. 2010; Li et al. 2013; Wang et al. 2014), Diptera (Liu et al. 2012), Neuroptera (Wang et al. 2010) and many others insects (Gao et al. 2012).

Material and methods

The fossil specimens were examined with a Leica M165C dissecting microscope and illustrated with the aid of a camera lucida attached to the microscope; drawings were scanned into a computer by EPSON5100 and were edited with Adobe Photoshop® CS3. Photographs of the specimens and magnified images of the details were taken with a digital camera system attached to the Leica M165C. Specimens were at times treated with ethanol (95%) on the surface to enhance the clarity and contrast. All type specimens are deposited in the Key Lab of Insect Evolution and Environmental Changes, the College of Life Sciences, Capital Normal University, Beijing, China (CNUB, Ren Dong, Curator). The wing venation nomenclature follows Byers (1979). The term of 'bittacid cross' is defined as the crossveins of [R_{4+5}-M_{1+2}, M_{1+2}-M_3] (Bechly and Schweigert 2000).

Table 1. A list of Bittacidae fossils described from China.

Genus	Species	Locality	Horizon/Age
Megabittacus Ren, 1997	*M. beipiaoensis* Ren, 1997	Beipiao, Liaoning	Yixian Fm.,K1
	M. colosseus Ren, 1997	Beipiao, Liaoning	Yixian Fm.,K1
	M. spatiosus Yang, Shih & Ren, 2012	Beipiao, Liaoning	Yixian Fm.,K1
Sibirobittacus Novokshonov, 1993	*S. atalus* Ren, 1997	Beipiao, Liaoning	Yixian Fm., K1
Neorthophlebia Handlirsch, 1906	*N. yunnanensis* Zhang & Hong, 2003	Tuodian, Yunnan	Tuodian Fm., J3
Decoribittacus Li & Ren, 2009	*D. euneurus* Li & Ren, 2009	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
	D. stictus Li & Ren, 2009	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
Exilibittacus Yang, Shih & Ren, 2012	*E. lii* Yang, Shih & Ren, 2012	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
	E. plagioneurus sp. n.	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
	E. foliaceus sp. n.	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
Formosibittacus Li, Ren & Shih, 2008	*F. macularis* Li, Ren & Shih, 2008	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
Jurahylobittacus Li, Ren & Shih, 2008	*J. astictus* Li, Ren & Shih, 2008	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
Karattacus Novokshonov, 1997	*K. longialatus* Li & Ren, 2009	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
Liaobittacus Ren, 1993	*L. longantennatus* Ren, 1993	Beipiao, Liaoning	Haifanggou Fm., J2
Preanabittacus Novokshonov, 1993	*P. validus* Yang, Shih & Ren, 2012	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
Mongolbittacus Petrulevičius, Huang & Ren, 2007	*M. daohugoensis* Petrulevičius, Huang & Ren, 2007	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
	M. speciosus sp. n.	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2
	M. oligophlebius sp. n.	Ningcheng, Inner Mongolia	Jiulongshan Fm., J2

Systematic paleontology

Order Mecoptera Packard, 1886
Infraorder Raptipeda Willmann, 1977
Family Bittacidae Handlirsch, 1906

Genus *Mongolbittacus* Petrulevičius, Huang & Ren, 2007

Type species. *Mongolbittacus daohugoensis* Petrulevičius, Huang & Ren, 2007

Included species. Type species, *Mongolbittacus speciosus* sp. n., and *Mongolbittacus oligophlebius* sp. n.

***Mongolbittacus speciosus* sp. n.**
http://zoobank.org/442F8176-318C-4671-8BA1-83B449A8F4C7
Figs 1–4

Etymology. The specific epithet is derived from a Latin word of *speciosus* (showy), highlighting the well-preserved wings in the holotype.

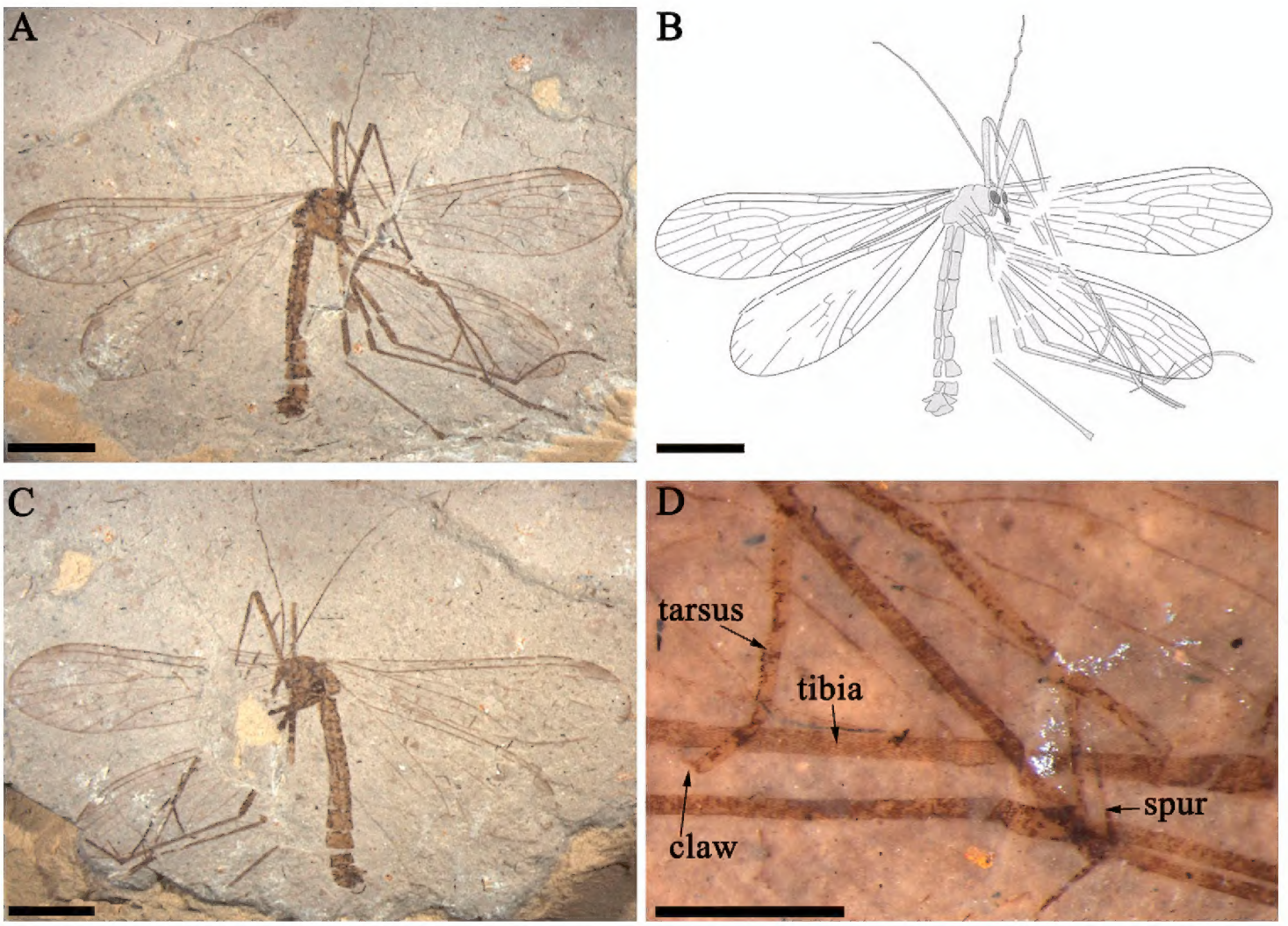

Figure 1. *Mongolbittacus speciosus* sp. n., holotype, CNU-MEC-NN2013008 P/C. **A** photo of part **B** line drawing of part **C** photo of counterpart **D** photo of legs, under alcohol. Scale bars represent 3 mm in **A–C**, 0.5 mm in **D**.

Holotype. A male specimen well-preserved, CNU-MEC-NN2013008 P/C, part and counterpart. Body 8.8 mm long; forewing 11.3 mm long with a maximal width of 3.0 mm; hind wing 9.1 mm long with a maximal width of 3.0 mm.

Horizon and locality. Jiulongshan Formation, late Middle Jurassic, Daohugou Village, Shantou Township, Ningcheng County, Inner Mongolia, China.

Diagnosis. In forewing, Sc reaching the anterior margin proximad of the forking of Rs; one crossvein between C and R_1; 1A and 2A fusing at base; and 2A sharply curving to the posterior margin.

Description. A male specimen in lateral view. The head oviform with robust and slender chewing mouthparts. Compound eyes large and oval. Antennae almost complete, filiform, about 6.9 mm long, comprising about twenty antennomeres; the lengths of basal antennomeres almost the same, but several apical antennomeres shorter than the basal ones. Thorax divided into pronotum, mesonotum and metanotum from the lateral view (Figs 1A–C, 4B, F).

Legs. Long and slender in lateral view, densely covered with short setae. But all legs fragmented due to poor preservation. Mesocoxa, metacoxa, trochanter visible in lateral view. Mid tibia 4.4 mm; tibial spurs long and sharp. Tarsus with 5 tarsomeres and a single pretarsal claw, but the fifth tarsomere not folded against the fourth as

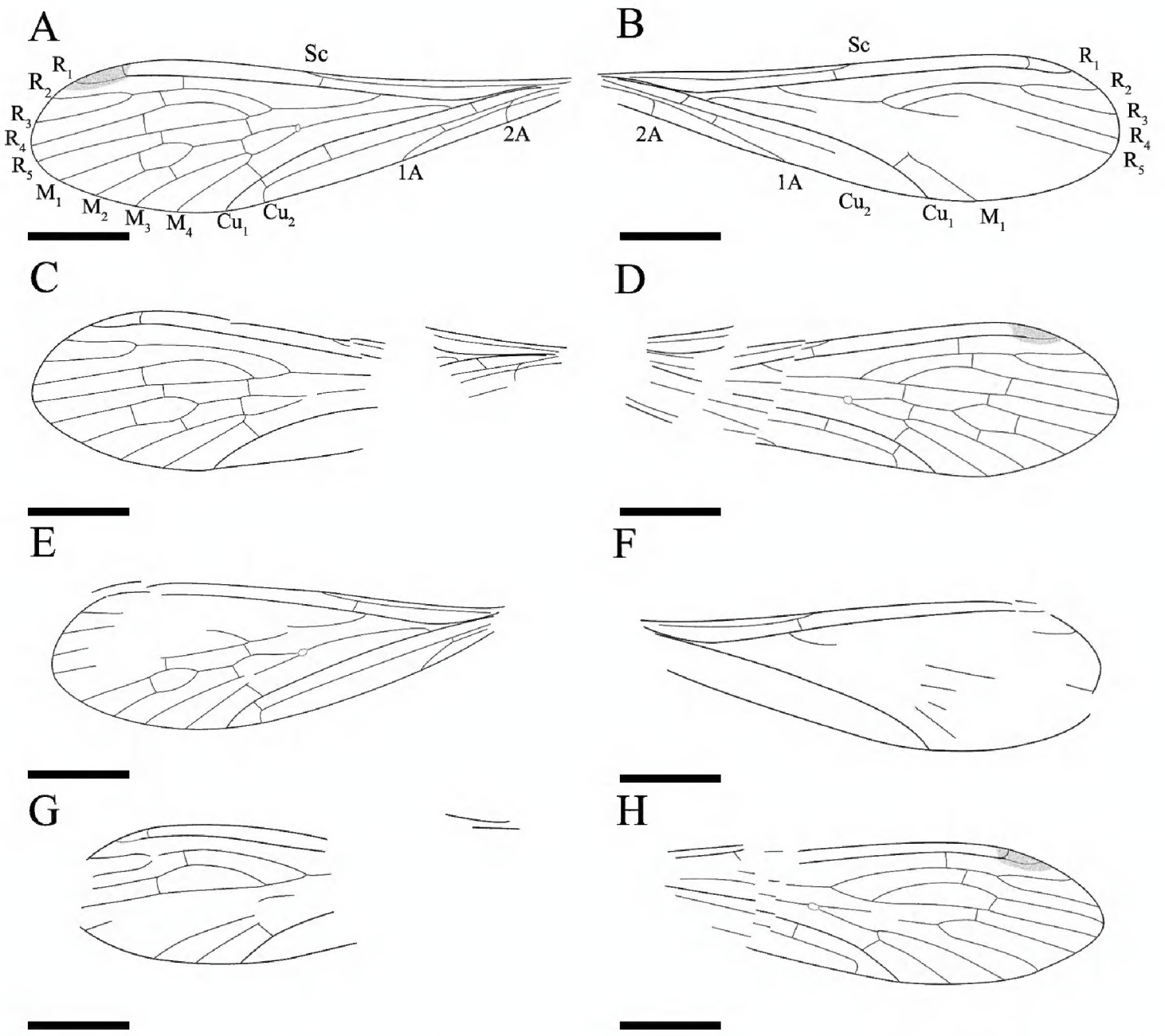

Figure 2. *Mongolbittacus speciosus* sp. n., holotype, CNU-MEC-NN2013008 P/C. Line drawings of part. **A** left forewing **D** right forewing **E** left hind wing **H** right hind wing. Line drawings of counterpart **B** right forewing **C** left forewing **F** right hind wing **G** left hind wing. Scale bars represent 1 mm in **A–H**.

preserved. In addition, the second and third tarsomeres covered with a few small spines (Fig. 1A–D).

Forewing. No maculation, base of wing narrow. Sc short, one oblique subcostal crossvein (Scv) between Sc and R_1; one crossvein between R_1 and C; R_1 smooth and reaching the dark pterostigmal area; Rs originating from R_1 at an acute angle; one crossvein between R_1 and R_{2+3}, one crossvein between R_{2+3} and R_4 and one crossvein between R_4 and R_5; the 'bittacid cross' not aligned, Z-shaped (in side view), and posterior part of 'the 'bittacid cross' distad of the forking of M_{3+4}; M with four branches and bifurcating proximad of the forking of Rs; one crossvein between R_5 and M_1, one between M_1 and M_2 and one between M_2 and M_3; M_4 simple, one long and oblique crossvein between M_4 and Cu_1; Cu_1 and M overlapping at base for a short distance; Cu_2 curving sharply with a 90° angle, reaching the posterior margin; Cu_1 and Cu_2 almost parallel, with three crossveins between them, the first oblique crossvein located

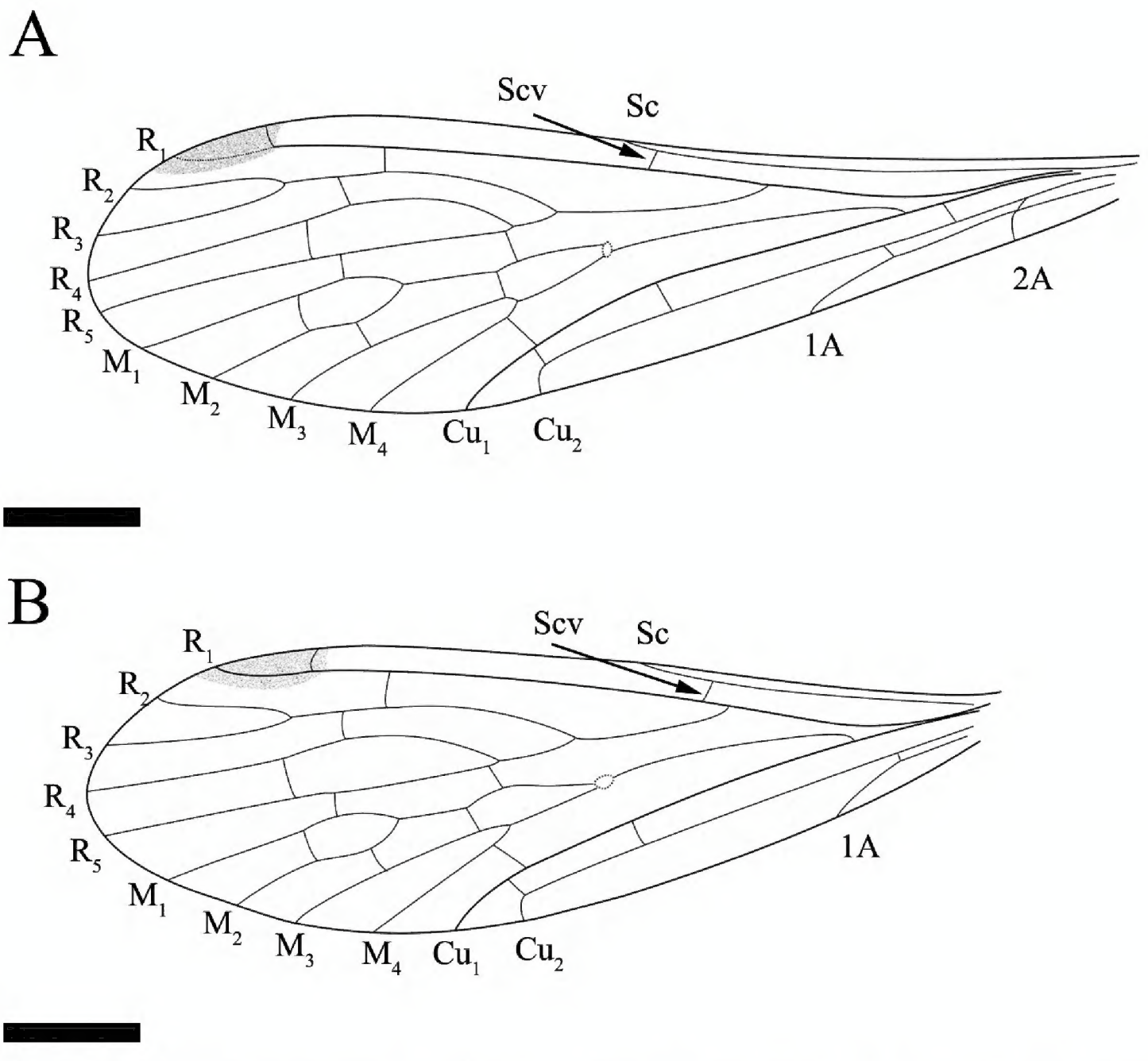

Figure 3. *Mongolbittacus speciosus* sp. n., holotype. **A** line drawing of forewing, composite of right and left forewings of part and counterpart **B** line drawing of hind wing, composite of right and left hind wings of part and counterpart. Scale bars represent 1 mm in **A–B**.

at the base of the wing, the second at the level of Scv, and the third near the sharp bending of Cu_2. Veins 1A and 2A fusing at base, 1A reaching the posterior margin proximad of the origination of Rs from R_1; two crossveins between 1A and Cu_2 (Figs 2A–D, 3A).

Hind wing. Sc short, reaching the anterior margin proximad of the forking of Rs; one crossvein between R_1 and C; One subcostal crossvein (Scv) between Sc and R_1, one crossvein between R_1 and R_{2+3}, and one short crossvein between R_{2+3} and R_4; R_4 sharply bending upwards, then parallel with R_5, one crossvein between them; the 'bittacid cross' not aligned, Z-shaped; M forking proximad of the bifurcation of Rs; one crossvein between R_5 and M_1, one between M_1 and M_2, one between M_2 and M_3 and one oblique crossvein between M_4 and Cu_1; Cu_1 and Cu_2 almost parallel with two crossveins between them; Cu_2 bending sharply with an 90° angle at the level slightly proximad of the forking of M_{3+4}; one crossvein between Cu_2 and 1A (Figs 2E–H, 3B).

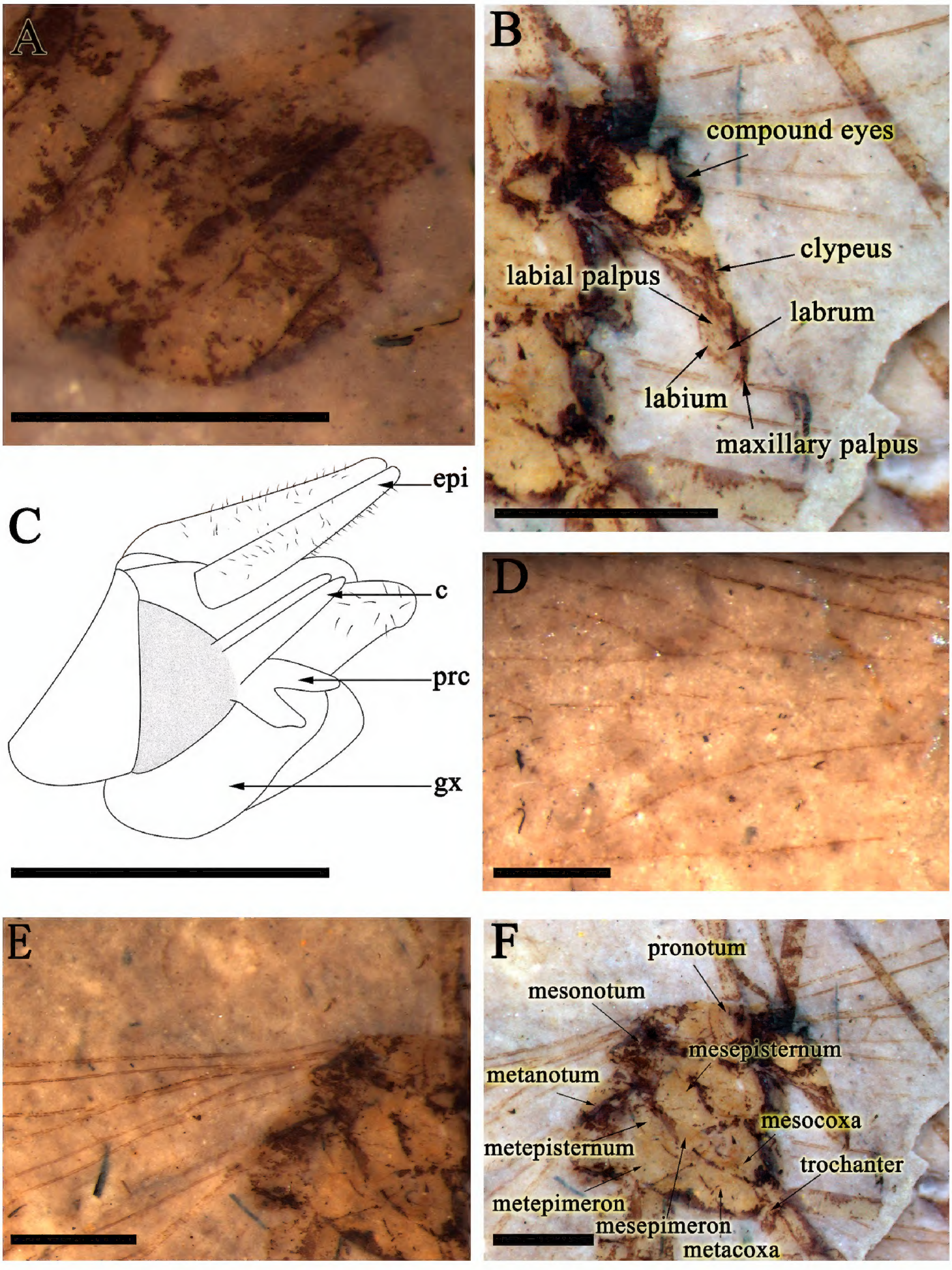

Figure 4. *Mongolbittacus speciosus* sp. n., holotype, photos under alcohol and a line drawing. **A** genitalia in lateral view **B** head **C** line drawing of genitalia in lateral view **D** vein M forking proximad of Rs forking in left forewing **E** anal field of left forewing; **F** thorax; Scale bars represent 0.5 mm in **A**, **C**, 1 mm in **B**, **D–F**. Abbreviations: c, cercus; epi, epiandrium; gx, gonocoxite; prc, procitiger.

Abdomen. Abdomen 6.5 mm long, with 9 visible segments. The ninth tergum (T9) connecting gonocoxite with dense short setae at the apex, epiandrium well-preserved with long setae on the surface; procitiger and cercus present in lateral view (Figs 1A–C, 4A, C).

Remarks. *Mongolbittacus speciosus* sp. n. (Figs 1–4) is assigned to the genus *Mongolbittacus* based on the following generic diagnostic characters: R_{4+5} plus R_4 distinctively curved; M_4 simple; the 'bittacid cross' not aligned; wide posterior anal field; and the forking of M proximad of the Rs forking. *M. speciosus* sp. n. is distinguished from the other two species of *Mongolbittacus* by veins of 1A and 2A fusing at base, and 2A sharply curving to the posterior margin, as shown in the key below.

Mongolbittacus oligophlebius sp. n.

http://zoobank.org/D4B8FBAC-45F0-4A31-B805-108FB33AC7B1

Figs 5, 6

Etymology. The specific name *oligophlebius* denotes the wing venation is simple with only a few crossveins.

Holotype. CNU-MEC-NN-2013009 P/C, part and counterpart. Forewing 12 mm long with a maximal width of 3.5 mm.

Paratype. CNU-MEC-NN-2013014.

Horizon and locality. Jiulongshan Formation, late Middle Jurassic, Daohugou Village, Ningcheng County, Inner Mongolia, China.

Diagnosis. The posterior part of the "bittacid cross' coinciding with the forking of M_{3+4}; one oblique crossvein between R_{2+3} and R_4 at the bifurcation of R_{2+3}; and length of R_3 0.9 times as long as R_{2+3}.

Description. Poorly preserved with only one complete forewing and the basal part of one hind wing. But the mid-tibia with two long spurs and five tarsomeres well-preserved, covered by dense short setae (Fig. 5A, B, D).

Forewing. Sc reaching the anterior margin proximad of the forking of Rs, one crossvein between C and R_1; one subcostal crossvein (Scv) between Sc and R_1; Rs bifurcating into four branches, one crossvein between R_1 and R_{2+3} and one oblique crossvein between R_{2+3} and R_4; Rs arising from R_1 at an acute angle; length of R_3 0.9 times as long as R_{2+3}; one crossvein between R_4 and R_5; M with four branches and bifurcating proximad of the forking of Rs; the 'bittacid cross' not aligned; the posterior part of the 'bittacid cross' coinciding with the forking of M_{3+4}; one crossvein between R_5 and M_1, one between M_1 and M_2 and one between M_2 and M_3; one crossvein between Cu_1 and M_4, Cu_1 and Cu_2 parallel with two crossveins between them; one crossvein between Cu_2 and 1A; 1A reaching the posterior margin distad of the origination of Rs from R_1; 2A bending sharply and reaching the posterior margin, a short crossvein between 1A and 2A (Figs 5C, E, 6C).

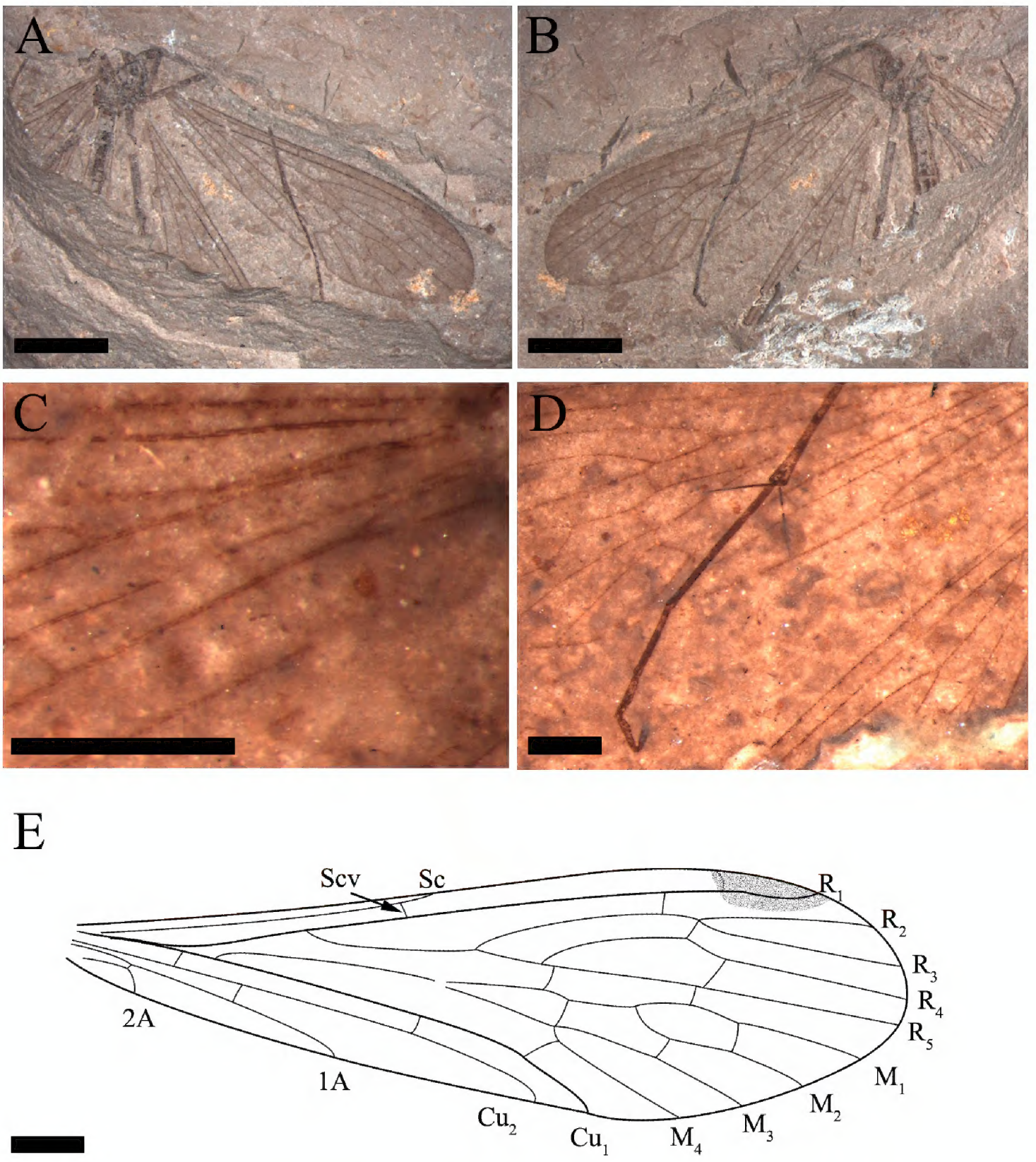

Figure 5. *Mongolbittacus oligophlebius* sp. n., holotype, CNU-MEC-NN-2013009 P/C. **A** photo of part **B** photo of counterpart **C** anal field of left forewing, under alcohol **D** photo of a leg, under alcohol **E** line drawing of right forewing of part. Scale bars represent 3 mm in **A–B**, 1 mm in **C–E**.

Remarks. *Mongolbittacus oligophlebius* sp. n. (Figs 5, 6) is assigned to the genus *Mongolbittacus* based on the following generic diagnostic characters: R_{4+5} plus R_4 distinctively curved; M_4 simple; the 'bittacid cross' not aligned; posterior anal field broad; and 2A bending sharply and reaching the posterior margin. This new species is differentiated from *M. daohugoensis* and *M. speciosus* sp. n. by characters as shown in the key below.

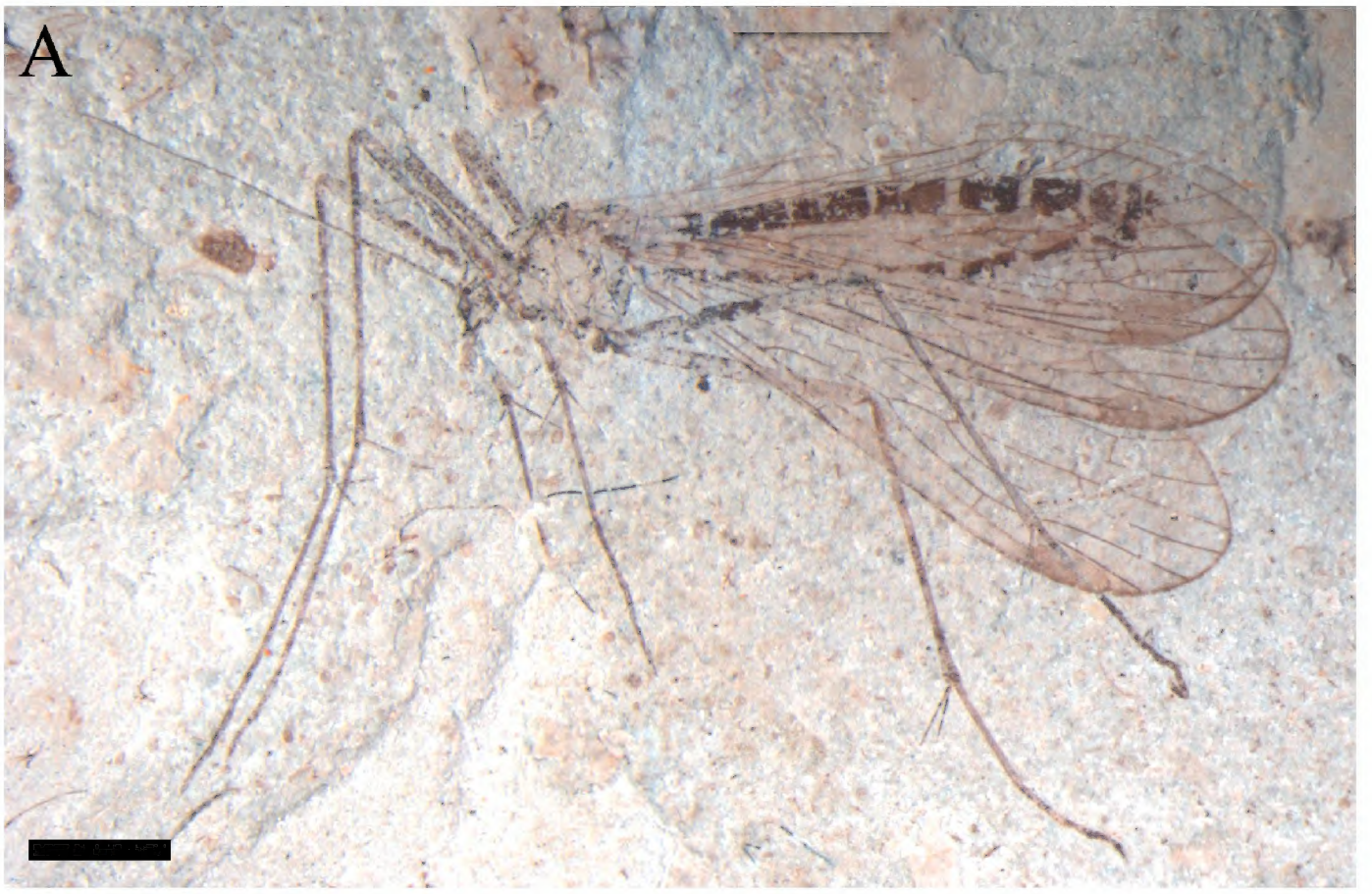

Figure 6. *Mongolbittacus oligophlebius* sp. n., paratype, CNU-MEC-NN-2013014. **A** photo **B** line drawing of part **C** line drawing of left forewing of part; Scale bars represent 2 mm in **A–B**, 1 mm in **C**.

Key to species of *Mongolbittacus* based on characters of the forewing

1 Sc reaching the anterior margin proximad of the forking of Rs (Figs 3A, 5E).... **2**
– Sc reaching the anterior margin distad of the forking of Rs..... ..... ***M. daohugoensis* Petrulevičius, Huang & Ren, 2007**
2 1A and 2A fusing at base (Fig. 3A) ..... ***M. speciosus* sp. n.**
– A short crossvein between 1A and 2A (Fig. 5E) ..... ***M. oligophlebius* sp. n.**

Exilibittacus Yang, Ren & Shih, 2012

Type species. *Exilibittacus lii* Yang, Ren & Shih, 2012.

Included species. Type species, *E. foliaceus* sp. n., and *E. plagioneurus* sp. n.

Emended diagnosis. Forewing: Sc reaching the anterior margin at the same level or proximad of the forking of R_{4+5}; the 'bittacid cross' aligned, the posterior of the 'bittacid cross' distad of the bifurcation of M_{3+4}; 1A terminating at the posterior margin at the same level or distad of the origination of Rs from R_1. Hind wing: Rs with three or four branches, M with three branches and 2A absent.

Exilibittacus foliaceus sp. n.

http://zoobank.org/98FF3AC2-E493-45B7-B351-27B42685200A
Fig. 7

Etymology. The Latin word of "*foliaceus*" means folliform, referring to the shape of the wings like leaves.

Holotype. Female, CNU-MEC-NN2013010, in dorsal view. Body length 12.9 mm, forewing 11.7 mm long and 2.9 mm wide; hind wing 9.7 mm long and 2.6 mm wide.

Horizon and locality. Jiulongshan Formation, late Middle Jurassic, Daohugou Village, Shantou Township, Ningcheng County, Inner Mongolia, China.

Diagnosis. Forewing: pterostigmal crossveins (Pcv) absent, but 2A present. Hind wing: Rs with four branches and the bifurcation of Rs at the same level of the bifurcation of M.

Description. A female holotype preserved in dorsal view. Antenna filiform, scape, pedicel and part of other antennomeres preserved. The vertex of the head raised. Legs not well-preserved, covered with short setae; the fifth tarsomere folded against the fourth, a claw present (Fig. 7A, B).

Forewing. The base of wings narrow, pterostigma slightly dark. Sc terminating at the anterior margin proximad of the R_{4+5} forking; one subcostal crossvein (Scv) between Sc and R_1; R_1 running straight through pterostigma, without sagging; one crossvein between R_1 and R_{2+3}; Rs with four branches, R_4 slightly curved at beginning and then parallel with R_5; one crossvein between R_{2+3} and R_4 and one crossvein between R_4 and R_5; M with four branches, M_{3+4} forking far proximad of the bifurcation of

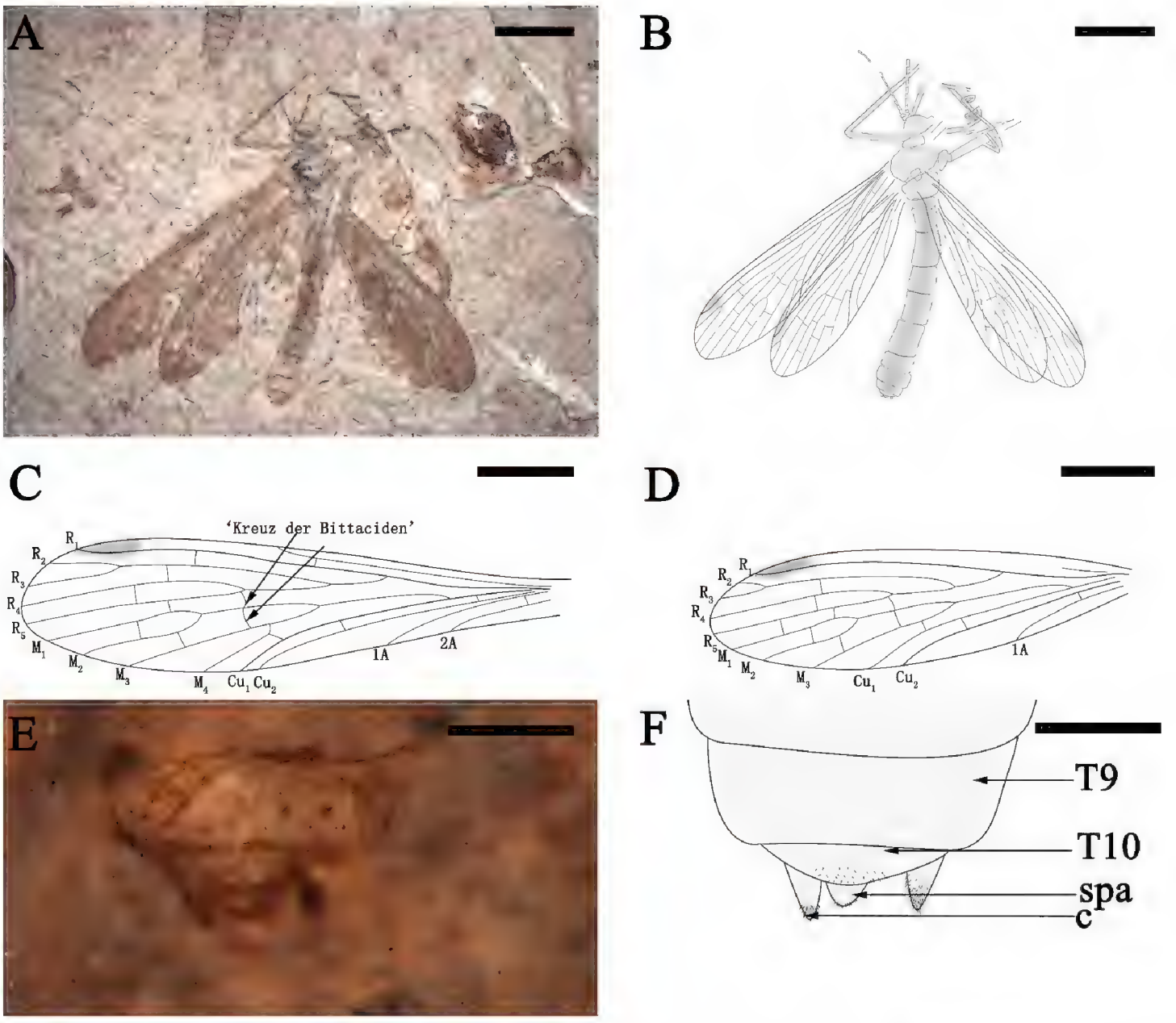

Figure 7. *Exilibittacus foliaceus* sp. n., holotype, CNU-MEC-NN2013010. **A** photo **B** line drawing **C** line drawing of left forewing **D** line drawing of left hind wing **E** photo of genitalia in dorsal view, under alcohol **F** line drawing of genitalia in dorsal view. Scale bars represent 3 mm in **A**, **B**, 2 mm in **C**, **D**, 0.5 mm in **E**, **F**. Abbreviations: T9, the ninth tergum; T10, the tenth tergum; c, cercus; spa, supraanale.

M_{1+2}; the 'bittacid cross' aligned and gently curved, posterior part of the 'bittacid cross' reaching M_3 distad of the M_{3+4} forking point; one crossvein between R_5 and M_1, one between M_1 and M_2 and one between M_2 and M_3; Cu_1 and Cu_2 almost parallel with two crossveins between them, one crossvein between M_4 and Cu_1; 1A and 2A simple and one crossvein between them; 1A reaching the posterior margin at the same level of the origination of Rs from R_1; 2A reaching the posterior margin at the same level of the origination point of M (Fig. 7C).

Hind wing. With the same shape as the forewing. R_1 running smoothly through pterostigma; pterostigmal crossveins (Pcv) absent; Rs with four branches; one crossvein between R_{2+3} and R_4 and one between R_4 and R_5; the 'bittacid cross' aligned; M divided into three branches; two crossveins between R_5 and M_1, one between M_1 and M_2, one between M_2 and M_3 and one between M_3 and Cu_1; Cu_1 and

Cu_2 parallel and with one crossvein between them. Vein 1A reaching the posterior margin at the level slightly proximad of the Rs originating from R_1, one crossvein between Cu_2 and 1A (Fig. 7D).

Abdomen. Abdomen 9.1 mm long, with ten visible segments. Female genital structure well-preserved from the dorsal view. Supraanale and cercus covered with small and short setae (Fig. 7A, B, E, F).

Remarks. *Exilibittacus foliaceus* sp. n. (Fig. 7) is assigned to the genus *Exilibittacus* Yang, Ren & Shih, 2012 based on the following generic diagnostic characters: in forewing, Sc reaching the anterior margin proximad of the forking of R_{4+5} and the 'bittacid cross' aligned; and in hind wing, Rs with four branches while M with three branches. *Exilibittacus foliaceus* sp. n. is distinguished from the other two species as shown by the key below.

***Exilibittacus plagioneurus* sp. n.**
http://zoobank.org/CCEF6E6E-B54D-43CB-8E24-F289597FB4C1
Figs 8, 9

Etymology. From Greek "*plagios*" (oblique) and "*neuron*" (vein), referring to oblique crossveins of the wings.

Holotype. Female, CNU-MEC-NN2013013 P/C, in dorsal view. Abdomen length 8.3 mm, forewing length 9.3 mm with a maximal width of 2.3 mm; hind wing length 8.4 mm with a maximal width of 2.2 mm.

Horizon and locality. Jiulongshan Formation, late Middle Jurassic, Daohugou Village, Shantou Township, Ningcheng County, Inner Mongolia, China.

Diagnosis. Forewing Sc terminating at the anterior margin at the same level of the R_{4+5} forking; Vein 1A terminating at the posterior margin distad of the origination of Rs from R_1.

Description. Female, small-sized, head not preserved but mesothorax and metathorax preserved. Legs partially preserved, one hind leg with five tarsomeres present but the pretarsal claw not preserved, the fifth tarsomere folded against the fourth; the first and second tarsomeres with several spines. (Fig. 8A–D)

Forewing. Wing narrow basally with obviously dark pterostigma. Sc long, reaching the anterior margin at the same level of the R_{4+5} forking; R_1 not forking, one subcostal crossvein (Scv) between Sc and R_1, Scv about 1/6 as long as the Sc length between Scv and the apex of Sc; one pterostigmal crossvein (Pcv) and one crossvein between R_1 and R_{2+3}; Rs with four branches, one crossvein between R_3 and R_4, one between R_{2+3} and R_4 and one between R_4 and R_5; M with four branches, M_4 base bending sharply; the 'bittacid cross' aligned, the posterior part of the 'bittacid cross' reaching M_3 distad of the M_{3+4} forking point; two crossveins between R_5 and M_1, one between M_1 and M_2 and one between M_2 and M_3; Cu_1 ending before the forking of R_{4+5}, one crossvein between M_4 and Cu_1, one between Cu_1 and Cu_2; one short

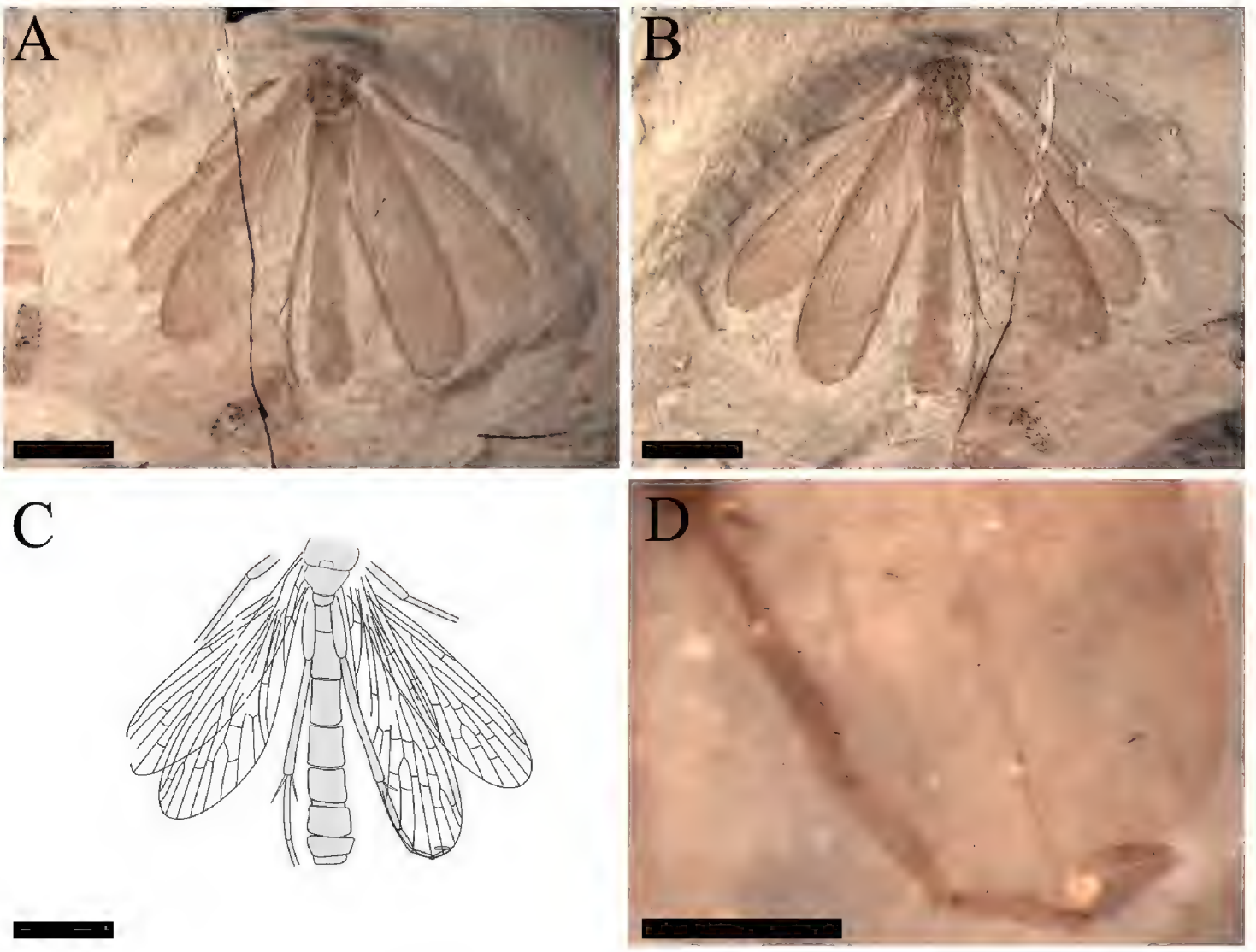

Figure 8. *Exilibittacus plagioneurus* sp. n., holotype, CNU-MEC-NN2013013 P/C, dorsal view. **A** photo of part **B** photo of counterpart **C** line drawing of part **D** photo of a hind leg, under alcohol. Scale bars represent 3 mm in **A–C**, 1 mm in **D**.

crossvein between Cu_2 and 1A; 1A terminating at the posterior margin distad of the origination of Rs; 2A ending proximad of the originations of Rs and M, one crossvein between 1A and 2A (Fig. 9A, C).

Hind wing. Sc short, reaching the anterior margin before the forking of R_{4+5}, one crossvein (Scv) between Sc and R_1; R_1 smooth and not sagging through the pterostigmal area; one pterostigmal crossvein (Pcv) present. Rs with three branches; one crossvein between R_1 and R_2, one between R_2 and R_3 and one between R_3 and R_4; M with three branches; two crossveins between R_4 and M_1, one between M_1 and M_2 and one between M_2 and M_3; the 'bittacid cross' not aligned; one between M_3 and Cu_1 and one between Cu_1 and Cu_2. Vein 1A terminating at the posterior margin distad of the origination of Rs, one crossvein between Cu_2 and 1A (Fig. 9B, D).

Abdomen. Ten segments visible, genital segments not preserved (Fig. 8A–C).

Remarks. *Exilibittacus plagioneurus* sp. n. (Figs 8, 9) is assigned to *Exilibittacus* Yang, Ren & Shih, 2012 based on the following generic diagnostic characters: in forewing, Sc reaching the anterior margin at the same level of the forking of R_{4+5} and the 'bittacid cross' aligned, and in hind wing, M with three branches. The new species is differentiated from *E. lii* and *E. foliaceus* sp. n. by characters shown in the key below.

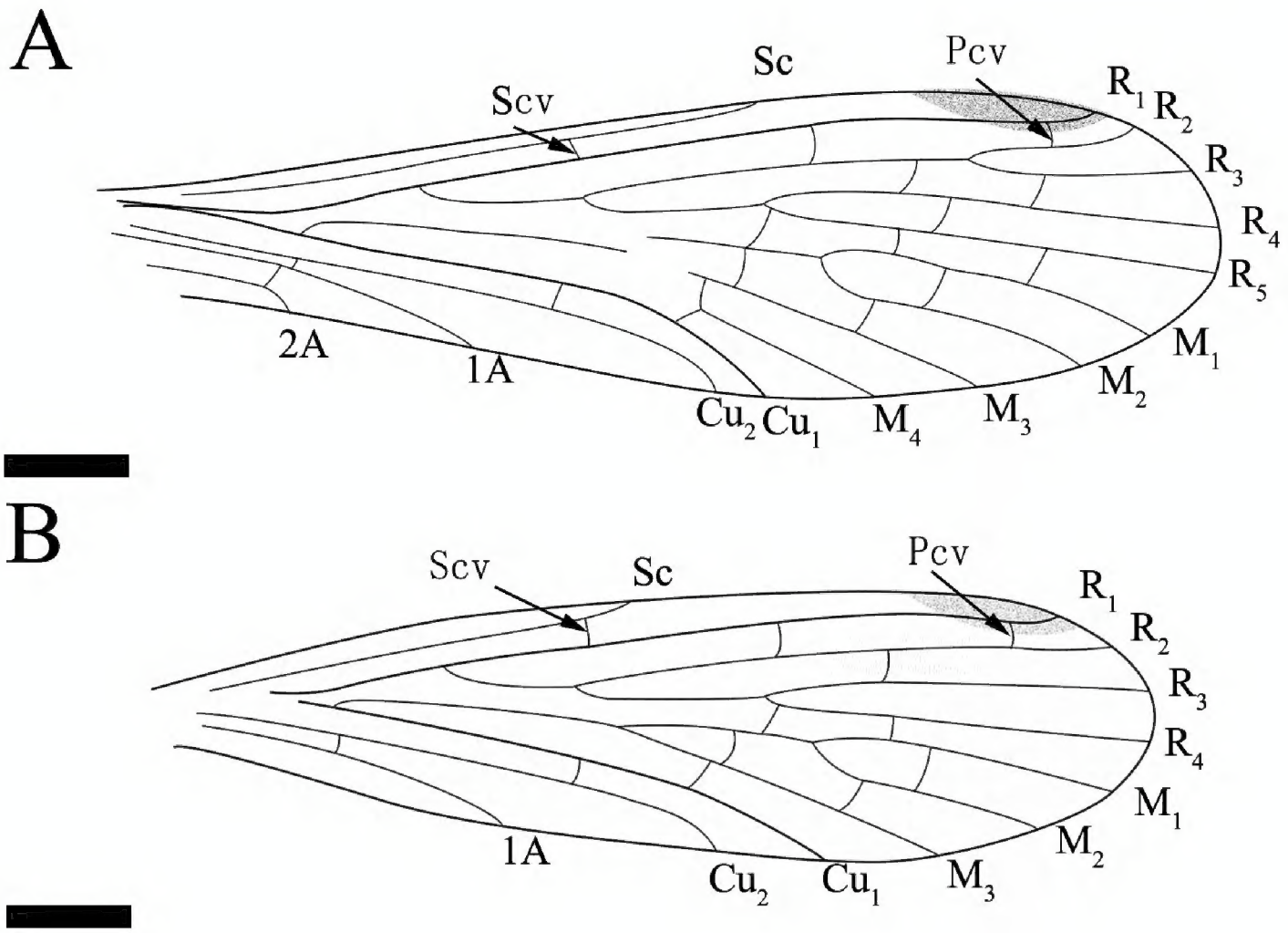

Figure 9. *Exilibittacus plagioneurus* sp. n., holotype. Line drawings of part. **A** right forewing of part **B** right hind wing of part **C** left forewing of part **D** left hind wing of part. Scale bars represent 1 mm in **A–D**.

Key to species of *Exilibittacus* based on characters of both fore- and hind-wings

1 Rs with four branches in hind wing (Fig. 7D).....***E. foliaceus* sp. n.**
– Rs with three branches in hind wing.....**2**
2 1A terminating at the posterior margin of the forewing distad of the origination of Rs (Fig. 9A).....***E. plagioneurus* sp. n.**
– 1A terminating at the posterior margin of the forewing proximad of the origination of R ..... ***E. lii* Yang, Ren & Shih, 2012**

Acknowledgements

We appreciate valuable suggestion and comments on our manuscript by Dr. Alexei Bashkuev. We are grateful to Dr. Yongjie Wang, Dr. Taiping Gao, Mei Wang, Qi Wang in the CNU Laboratory for their help and assistance to the first author. This research is supported by the National Basic Research Program of China (973 Program; 2012CB821906), the National Natural Science Foundation of China (31230065, 41272006). Great Wall Scholar and KEY project of the Beijing Municipal Commission of Education (KZ201310028033) and Program for Changjiang Scholars and Innovative Research Team in University (IRT13081).

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